IS 8161-5 (2011): Guide for Equipment Reliability Testing, Part 5: Compliance Test Plans for Success Ratio [LITD 2: Reliability of Electronic and Electrical Components and Equipment]

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IS : 8161 (Part V) - 1981
(Reaffirmed 2002)

Indian Standard

GUIDE FOR EQUIPMENT RELIABILITY TESTING

PART V COMPLIANCE TEST PLANS FOR SUCCESS RATIO

UDC 621·31+621·38·038 : 621-192 : 620·113·2

INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Price Rs 7·00

November 1981

Indian Standard

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PART V COMPLIANCE TEST PLANS FOR SUCCESS RATIO

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GUIDE FOR EQUIPMENT RELIABILITY TESTING

PART V COMPLIANCE TEST PLANS FOR SUCCESS RATIO

0. FOREWORD

0.1 This Indian Standard (Part V) was adopted by the Indian Standards Institution on 21 April 1981, after the draft finalized by the Reliability of Electronic and Electrical Components and Equipment Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 This standard which deals with the reliability requirements when these are expressed as a success ratio is the fifth in the series of Indian Standards for equipment reliability testing. To be able to write a detailed reliability test specification and perform a reliability test, the test engineer will need additional information which are dealt with in detail in other standards in this series. A list of standards envisaged in this series some of which are under consideration is given on page 14.

0.3 This standard is based on IEC Document 56 (Central Office) 74 'Draft-Equipment reliability testing: Part 5 Compliance test plans for success ratio' issued by the International Electrotechnical Commission.

0.4 This standard is one of a series of Indian Standards on reliability of electronic and electrical components and equipment.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part V) covers reliability requirements when these are expressed as a success ratio.

*Rules for rounding off numerical values (*revised*).

1.2 The test plans given in this standard are applicable to reusable as well as non-reusable (one-shot) devices. Reusable devices may be repaired between successive trials, provided that the state and performance are the same at the start of all trials. For non-reusable devices, one test item is used for each trial.

NOTE — These plans are based on the assumption that each trial is statistically independent.

2. TERMINOLOGY

2.0 For the purpose of this standard, the terms and definitions covered in IS : 1885 (Part XXXIX)-1979* shall apply in addition to the following.

2.1 Specified Success Ratio — This is the probability, that an item will perform a required function, or a trial will be successful, under stated conditions.

2.2 Observed Success Ratio — This is the ratio of the number of non-failed items or trials at the completion of testing to the total number of test items or occasions of trial.

2.3 Producer's Risk — The probability of rejection if the equipment has the acceptance value of the specified reliability characteristic.

2.4 Consumer's Risk — The probability of acceptance if the equipment has the unacceptable value of the specified reliability characteristic.

3. LIST OF SYMBOLS

3.1 The characteristics and symbols used in this standard are:

- a = intercept values of the accept and reject lines on the vertical axis of the sequential test diagram (*see* Fig. 1)
- n_f = fixed number of trials required for acceptance
- n_s = accumulated number of trials in a sequential test plan
- n_t = number of trials at truncation (*see* Fig. 1)
- r = accumulated number of failures
- r_{Re} = number of failures for rejection
- r_t = number of failures at truncation (*see* Fig. 1)
- R = true value of success ratio
- R_0 = acceptable value of success ratio
- R_1 = unacceptable value of success ratio

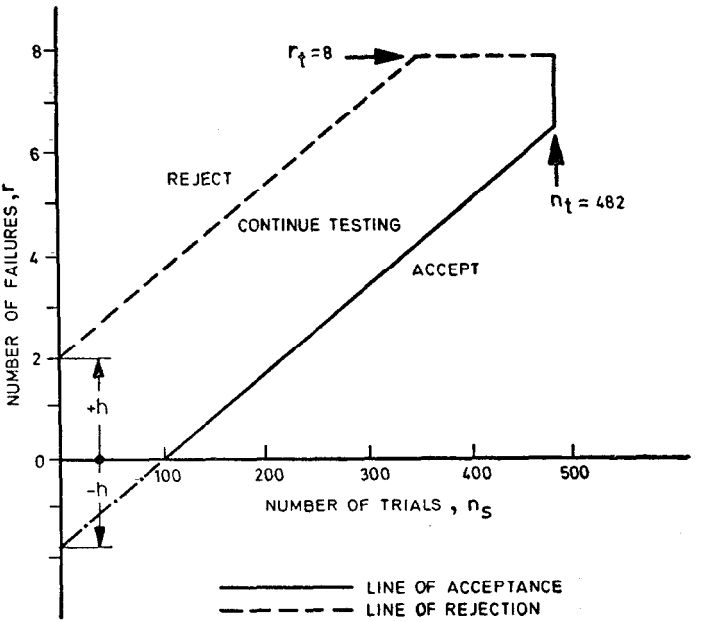
*Electrotechnical vocabulary: Part XXXIX Reliability of electronic and electrical items (*first revision*).

s = slope of accept and reject lines in the sequential test diagram (*see* Fig. 1)

α = (nominal) producer's risk, that is, probability of rejection when $R = R_0$

β = (nominal) consumer's risk, that is, probability of acceptance when $R = R_1$

$D_R = \left[\frac{1 - R_1}{1 - R_0}\right]$ discrimination ratio associated with success ratio



$R_0 = 0{\cdot}99$, $D_R = 3{\cdot}0$ ($R_1 = 0{\cdot}97$)

$\alpha = \beta = 0{\cdot}10$, $n_t = 482$, $r_t = 8$

FIG. 1 EXAMPLE OF A TRUNCATED SEQUENTIAL TEST

4. STATISTICAL TEST PLANS AND GENERAL TEST PROCEDURE

4.1 Test plans are given for two types of tests:

a) Truncated sequential tests, and

b) Fixed number of trials.

4.1.1 A trial is defined as the operation or cycle described in the detailed reliability test specification that is to be applied to the test item(s).

4.2 These plans are based on the binomial distribution and characterized by the parameters R_O, D_R, α and β. The true producer's and consumer's risks for the test plans differ slightly from the nominal characteristics α and β due to the necessary approximations to whole numbers and to the truncation of the sequential tests.

4.3 The detailed reliability test specification shall state which type of test and test plan are to be used. Guidance for the choice of type of test is similar to that given in **8.4** of IS : 8161 (Part I)-1976* for truncated sequential and time/failure terminated tests when the reliability characteristic is a function of time.

4.4 The test items shall be subjected to the number of trials according to the relevant test plan. For reusable and/or repairable devices, the detailed reliability test specifications should preferably state the number of test items as well as the maximum number of trials for each test item. The total number of possible trials shall suit the test plan used. The number of relevant failures [*see* **10.2** of IS : 8161 (Part I)-1976*] is counted and compared with the decision criteria of the test plan.

5. TRUNCATED SEQUENTIAL TEST PLANS

5.1 Table 1 gives the appropriate test plans for various values of the specified R_O, D_R, α and β. The table contains parameter values of h, s, n_t, r_t for each test plan, the meanings of which are shown in Fig. 1. Criteria are based on the following bases:

Accept when $r \leqslant sn_s - h$

Reject when $r \geqslant sn_s + h$

Continue when $sn_s - h < r < sn_s + h$

5.1.1 The sequential test plans shall be truncated at lines based on the values given in Table 1. The accept/reject criteria are thereby completed by the following bases:

Accept when $r < r_t$ at $n_s = n_t$

Reject when $r \geqslant r_t$

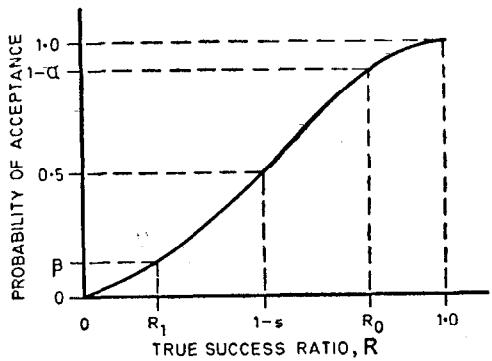
5.1.2 The accumulated results are checked against criteria after each trial, and if the test is to continue, another trial is performed.

NOTE — The truncation affects the true values of α and β. However, the truncation values of Table 1 are chosen so that the maximum true values of α and β are less than 0·055, 0·105, 0·205 and 0·305 for normal values 0·05, 0·10, 0·20 and 0·30 respectively. The truncation values were obtained from a computer programme which calculated the actual values of α and β for increasing values of n_t and r_t until the maximum values were within the above stated bounds.

*Guide for equipment reliability testing: Part I Principles and procedures.

5.2 Operating Characteristic Curve

5.2.1 For any of the truncated sequential tests, the following approximate points on the operating characteristic (OC) curve (*see* Fig. 2) are given.

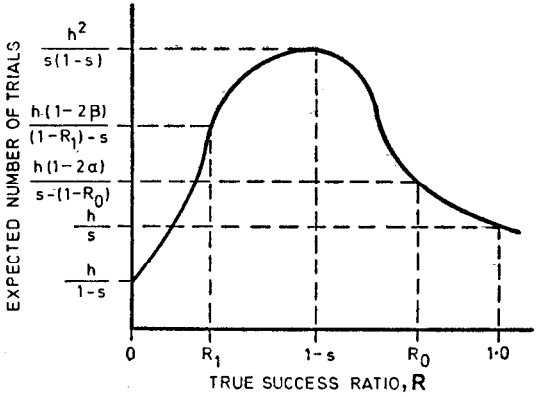


True Success Ratio R	Probability of Acceptance
1·0	1·0
R_0	$1-\alpha$
$1-s$	0·5
R_1	
0	0

FIG. 2 OPERATING CHARACTERISTIC CURVE

5.3 Expected Number of Trials to Decision

5.3.1 For any of the truncated sequential test plans, the following approximate points may be determined for the curve of the expected number of trials to decision *versus* the true success ratio (*see* Fig. 3).



True Success Ratio, R	Expected Number of Trials, n_R
1·0	$\frac{h}{s}$
R_0	$\frac{h(1-2\alpha)}{s-(1-R_0)}$
$(1-s)$	$\frac{h^2}{s(1-s)}$
R_1	$\frac{h(1-2\beta)}{(1-R_1)-s}$
0	$\frac{h}{1-s}$

FIG. 3 CURVE OF EXPECTED NUMBER OF TRIALS

5.4 Alternate Test Plans

5.4.1 If test plans are needed that are not given in Table 1, the values of s and h may be evaluated by the following equations which are valid only when $\alpha=\beta$.

$$s = \frac{\log_e\left(\frac{R_0}{R_1}\right)}{\log_e\left(\frac{R_0}{R_1}\right)-\log_e\left(\frac{1-R_0}{1-R_1}\right)}$$

$$h = \frac{\log_e\left(\frac{1-\beta}{\alpha}\right)}{\log_e\left(\frac{R_0}{R_1}\right)-\log_e\left(\frac{1-R_0}{1-R_1}\right)}$$

5.4.2 Truncation values may be interpolated from values within the table and should not be extrapolated beyond the ranges of R_0, D, α and β in Table 1.

6. TEST PLANS FOR FIXED NUMBER OF TRIALS

6.1 Table 2 gives the appropriate test plans for various values of the specified R_0, D_R, α and β. The table contains the number of trials, n_t, required to make an accept decision and the number of failures, r_{Re}, for a reject decision.

Example:

$R_0=0{\cdot}99$, $D_R=3{\cdot}0$ ($R_1=0{\cdot}97$). $\alpha=\beta=0{\cdot}10$. From Table 2 a number of trials $n_t=308$ would be required and a reject decision is made if $r_{Re}=6$ or more failures are observed.

6.2 Indian Standard Sampling plans and procedures for inspection by attributes for electronic items (*under preparation*) may be used for compliance test plans for success ratio. They are, however, not based on fixed risks. If this standard is used as a basis for reliability testing, the test plans have the producer's risk range from 0·01 to 0·20 and the specified success ratio R_0 is equal to one minus the AQL (Acceptable Quality Level). The test plans give the required number of trials (sample size) and the acceptance and rejection numbers for a large number of test plans. This standard does not generally use the consumer's risk as a basis for determining the number of trials.

TABLE 1 TRUNCATED SEQUENTIAL TESTS

(*Clauses* 5.1, 5.1.1, 5.1.2, 5.4.1 *and* 5.4.2)

R_0	DR	s	$\alpha = \beta = 0.05$			$\alpha = \beta = 0.10$			$\alpha = \beta = 0.20$			$\alpha = \beta = 0.30$		
			h	n_t	r_t	h	n_t	r_t	h	n_t	r_t	h	n_t	r_t
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
0·999 5	1·50	0·000 62	7·257 4	207 850	122	5·415 7	125 370	73	3·416 9	50 249	29	2·088 4	17 641	10
	1·75	0·000 67	5·258 0	97 383	60	3·923 7	58 035	36	2·475 6	22 665	14	1·513 1	3 201	5
	2·00	0·000 72	4·244 9	57 176	38	3·167 6	33 121	22	1·998 6	13 361	9	1·221 5	4 396	3
	3·00	0·000 91	2·677 7	17 223	14	1·998 2	9 873	8	1·260 7	3 434	3	0·770 5	1 945	2
0·999 0	1·50	0·001 23	7·252 9	102 220	121	5·412 3	61 291	72	3·414 8	25 125	29	2·087 1	8 819	10
	1·75	0·001 34	5·254 5	47 677	60	3·921 0	29 040	36	2·473 9	11 334	14	1·512 0	4 093	5
	2·00	0·001 44	4·241 8	28 536	38	3·165 4	16 563	22	1·997 1	6 930	9	1·220 6	2 197	3
	3·00	0·001 82	2·675 3	8 609	14	1·996 4	4 932	8	1·259 6	1 718	3	0·769 8	973	2
0·995	1·50	0·006 17	7·217 1	20 038	119	5·385 6	12 037	71	3·397 9	5 025	29	2·076 8	1 766	10
	1·75	0·006 70	5·226 3	9 269	59	3·900 0	5 561	35	2·460 6	2 269	14	1·503 9	817	5
	2·00	0·007 22	4·217 3	5 458	37	3·147 1	3 296	22	1·985 6	1 384	9	1·213 6	439	3
	3·00	0·009 11	2·655 7	1 540	13	1·981 8	971	8	1·250 4	342	3	0·764 2	194	2
3·990	1 50	0·012 33	7·172 3	9 803	117	5·352 2	5 912	70	3·376 9	2 508	29	2·063 9	883	10
	1·75	0·013 41	5·191 0	4 530	58	3·873 7	2 765	35	2·444 0	1 129	14	1·493 8	406	5
	2·00	0·014 44	4·186 6	2 634	36	3·124 2	1 638	22	1·971 1	691	9	1·204 7	220	3
	3·00	0·018 24	2·631 3	767	13	1·963 5	482	8	1·238 8	173	3	0·757 2	97	2
0·980	1·50	0·024 67	7·082 7	4 713	113	5·285 3	2 856	68	3·334 7	1 196	28	2·038 1	439	10
	1·75	0·026 82	5·120 4	2 169	56	3·821 0	1 329	34	2·410 8	560	14	1·473 5	204	5
	2·00	0·028 89	4·125 2	1 263	35	3·078 4	767	21	1·942 2	340	9	1·187 1	108	3
	3·00	0·036 55	2·582 2	374	13	1·926 9	234	8	1·215 7	83	3	0·743 1	48	2
0·970	1·50	0·037 01	6·993 1	3 015	109	5·218 4	1 833	66	3·292 5	760	27	2·012 3	291	10
	1·75	0·040 25	5·049 8	1 389	54	3·768 3	827	32	2·377 5	371	14	1·453 1	134	5
	2·00	0·043 36	4·063 7	817	34	3·032 5	481	20	1·913 3	193	8	1·169 4	73	3
	3·00	0·054 93	2·532 9	228	12	1·890 1	152	8	1·192 5	57	3	0·728 9	32	2
0·960	1·50	0·049 36	6·903 4	2 220	107	5·151 5	1 356	65	3·250 3	571	27	1·986 5	216	10
	1·75	0·053 69	4·979 1	1 017	53	3·715 5	619	32	2.344 2	255	13	1·432 8	101	5
	2·00	0·057 85	4·002 2	589	33	2·986 5	361	29	1·884 3	146	8	1·151 7	55	3
	3·00	0·073 39	2·483 5	170	12	1 853 2	99	7	1·169 3	43	3	0·714 6	24	2

0·950	1 50	0·051 71	6·813 7	1 721	105	5·084 6	1 047	63	3 208 0	436	26	1·960 7	176	10
	1·75	0·067 14	4·908 3	781	51	3·662 7	476	31	2·310 9	201	13	1·412 4	79	5
	2·00	0·072 36	3·940 6	455	32	2·940 6	286	20	1·855 3	116	8	1·133 9	43	3
	3·00	0·091 93	2·433 7	133	12	1·816 1	79	7	1·145 9	32	5	0·700 3	19	2
0·940	1·50	0·074 07	6·724 0	1 419	103	5·017 6	857	62	3·165 8	363	26	1·934 9	126	9
	1·75	0·080 60	4·837 5	636	50	3·609 9	383	30	2·277 6	167	13	1·392 0	65	5
	2·00	0·086 89	3·878 8	366	31	2·894 5	238	20	1·826 2	94	8	1·116 2	36	3
	3 00	0·110 57	2·383 8	103	11	1·778 9	62	7	1·122 3	26	3	0·686 0	16	2
0·930	1·50	0·086 43	6·634 2	1 177	100	4·950 6	722	61	3·123 5	299	25	1·909 1	108	9
	1·75	0·094 07	4·766 6	533	49	3·557 0	327	30	2·244 2	143	13	1·371 6	56	5
	2·00	0·101 44	3·817 0	303	30	2·848 4	192	19	1·797 1	82	8	1·098 4	31	3
	3·00	0·129 30	2·333 6	86	11	1·741 4	54	7	1·098 7	23	3	0·671 5	13	2
0·920	1·50	0·988 0	6·544 4	1 008	98	4·883 6	609	59	3·081 2	249	24	1·883 2	93	9
	1·75	0·107 55	4·695 6	455	48	3·504 0	276	30	2·210 8	115	12	1·351 2	49	5
	2·00	0·116 02	3·755 1	264	30	2·802 2	158	18	1·768 0	70	8	1·080 6	26	3
	3·00	0·148 14	2·283 1	74	11	1·703 7	46	7	1·074 9	19	3	0·657 0	11	2
0·910	1·50	0·111 17	6·454 6	881	86	4·816 6	589	57	3·038 9	220	24	1·857 4	85	9
	1·75	0·121 05	4·624 6	395	47	3·451 0	236	29	2·177 4	102	12	1·330 8	43	5
	2·00	0·130 62	3·693 1	234	30	2·755 9	132	17	1·738 8	63	8	1·062 7	22	3
	3·00	0·167 09	2·232 3	64	11	1·665 8	39	6	1·051 0	17	3	0·642 4	10	2
0·900	1·50	0·123 55	6·364 7	772	85	4·749 5	461	56	2·996 6	190	23	1·831 5	75	9
	1·75	0·134 56	4·553 5	343	46	3·398 0	212	28	2·143 9	92	12	1·310 3	38	5
	2·00	0·145 24	3·630 9	204	28	2·709 5	119	17	1·709 5	49	7	1·044 8	20	3
	3·00	0·186 17	2·181 2	54	10	1·627 7	32	6	1·026 9	15	3	0·627 7	9	2
0·850	1·50	0·185 55	5·914 4	457	84	4·413 5	278	51	2·784 6	114	21	1·702 0	53	8
	1·75	0·202 36	4·196 8	204	41	3·131 8	119	24	1·975 9	55	11	1·207 7	21	4
	2·00	0 218 82	3·318 4	115	25	2·476 3	69	15	1·562 4	31	7	0·954 9	13	3
	3·00	0·283 79	1·919 5	31	9	1·432 4	19	6	0·903 8	9	3	0·552 4	6	2
0·800	1·50	0·247 74	5·462 8	304	75	4·076 5	187	46	2·572 0	77	19	1·572 0	28	7
	1·75	0·270 63	3·837 6	137	37	2·863 7	81	22	1·806 8	36	10	1·104 3	13	4
	2·00	0·293 30	3·002 0	78	23	2·240 2	44	13	1·413 4	20	6	0·863 9	10	2
	3 00	0·386 85	1·643 3	17	7	1·226 3	12	5	0·773 7	5	2	0·472 9	4	2

TABLE 2 FIXED NUMBER OF TRIALS

(*Clause* 6.1)

R_O	D_R	$\alpha = 0{\cdot}05$ $\beta = 0{\cdot}05$		$\alpha = 0{\cdot}10$ $\beta = 0{\cdot}10$		$\alpha = 0{\cdot}20$ $\beta = 0{\cdot}20$		$\alpha = 0{\cdot}30$ $\beta = 0{\cdot}30$	
		nf	rRe	nf	rRe	nf	rRe	nf	rRe
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
0·999 5	1·50	108 002	67	65 849	41	28 584	18	10 814	7
	1·75	51 726	35	32 207	22	14 306	10	5 442	4
	2·00	31 410	23	20 125	15	9 074	7	3 615	3
	3·00	10 467	10	6 181	6	2 852	3	1 626	2
0·999 0	1·50	53 998	67	32 922	41	14 291	18	5 407	7
	1·75	25 861	35	16 102	22	7 152	10	2 721	4
	2·00	15 703	23	10 061	15	4 537	7	1 807	3
	3·00	5 232	10	3 090	6	1 426	3	813	2
0·995 0	1·50	10 647	66	6 851	41	2 857	18	1 081	7
	1·75	5 168	35	3 218	22	1 429	10	544	4
	2·00	3 137	23	1 893	14	906	7	361	3
	3·00	1 044	10	617	6	285	3	162	2
0·990 0	1·50	5 320	66	3 215	40	1 428	18	540	7
	1·75	2 581	35	1 607	22	714	10	272	4
	2·00	1 567	23	945	14	453	7	180	3
	3·00	521	10	308	6	142	3	81	2
0·980 0	1·50	2 620	65	1 605	40	713	18	270	7
	1·75	1 288	35	770	21	356	10	136	4
	2·00	781	23	471	14	226	7	90	3
	3·00	259	10	153	6	71	3	40	2
0·970 0	1·50	1 720	64	1 044	39	450	17	180	7
	1·75	835	34	512	21	237	10	90	4
	2·00	519	23	313	14	150	7	60	3
	3·00	158	9	101	6	47	3	27	2
0·960 0	1·50	1 288	64	782	39	337	17	135	7
	1·75	625	34	383	21	161	9	68	4
	2·00	374	22	234	14	98	6	45	3
	3·00	117	9	76	6	35	3	20	2
0·950 0	1·50	1 014	63	610	38	269	17	108	7
	1·75	486	33	306	21	129	9	54	4
	2·00	298	22	187	14	78	6	36	3
	3·00	93	9	60	6	28	3	16	2
0·940 0	1·50	832	62	508	38	224	17	90	7
	1·75	404	33	244	20	107	9	45	4
	2·00	248	22	155	14	65	6	30	3
	3·00	77	9	50	6	23	3	13	2

(*Continued*)

TABLE 2 FIXED NUMBER OF TRIALS — *Contd*

R_O	D_R	$\alpha = 0{\cdot}05$ $\beta = 0{\cdot}05$		$\alpha = 0{\cdot}10$ $\beta = 0{\cdot}10$		$\alpha = 0{\cdot}20$ $\beta = 0{\cdot}20$		$\alpha = 0{\cdot}30$ $\beta = 0{\cdot}30$	
		nf	r_{Re}	nf	r_{Re}	nf	r_{Re}	nf	r_{Re}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
0·930 0	1·50	702	61	424	37	192	17	77	7
	1·75	336	32	208	20	92	9	38	4
	2·00	203	21	125	13	55	6	25	3
	3·00	66	9	42	6	20	3	11	2
0·920 0	1·50	613	61	371	37	168	17	67	7
	1·75	294	32	182	20	80	9	34	4
	2·00	117	21	109	13	48	6	22	3
	3·00	57	9	37	6	17	3	10	2
0·910 0	1·50	536	60	329	37	149	17	60	7
	1·75	253	31	154	19	71	9	30	4
	2·00	157	21	96	13	43	6	20	3
	3·00	51	9	33	6	15	3	9	2
0·900 0	1·50	474	59	288	36	134	17	53	7
	1·75	227	31	138	19	64	9	27	4
	2·00	135	20	86	13	39	6	18	3
	3·00	41	8	25	5	14	3	8	2
0·850 0	1·50	294	55	181	34	79	15	35	7
	1·75	141	29	87	18	42	9	18	4
	2·00	85	19	53	12	21	5	12	3
	3·00	26	8	16	5	9	3	5	2
0·800 0	1·50	204	51	127	32	55	14	26	7
	1·75	98	27	61	17	28	9	13	4
	2·00	60	18	36	11	19	6	9	3
	3·00	17	7	9	4	4	2	4	2

INDIAN STANDARDS

ON

EQUIPMENT RELIABILITY TESTING

IS:

8161 Guide for equipment reliability testing:

(Part I)-1976	Principles and procedures
(Part II)	Design for test cycles (*under preparation*)
(Part III)	Preferred test conditions for equipment reliability testing (*under consideration*)
(Part IV)	Procedures for determining point estimates and confidence limits from equipment reliability determination tests (*under consideration*)
(Part V)-1981	Compliance test plans for success ratio
(Part VI)	Tests for the validity of a constant failure rate assumption (*under preparation*)
(Part VII)-1977	Compliance test plans for failure rate and mean time between failures assuming constant failure rate
(Part VIII)	Tests for the validity of a non-constant failure rate assumption (*under consideration*)
(Part IX)	Compliance tests plans assuming Weibull distribution of times to failure (*under consideration*)
(Part X)	Compliance test plans assuming normal distribution of times to failure (*under consideration*)
(Part XI)	Flow chart describing preparations for and execution of reliability tests